

Diffusion Characteristics of Geosynthetic Clay Liners Amended with Partial Replacement of Bentonite by Flyash

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Abstract- Geosynthetic Clay Liners (GCL) are extensively used to replace clay liners in the waste containments. GCL is made by stitching two layers of geotextile with bentonite as hydraulic barrier between the geo textiles. Many researchers have reported on the diffusion characteristics of metal ions through GCL. Addition or partial replacement of Bentonite in GCL, with industrial wastes such as Flyash, Silicafume, Ground Granulated Blast Furnace Slag (GGBS) make the GCL more economical. These industrial wastes are abundantly available, very fine and their use in GCL is an eco-friendly alternative to reduce their environmental pollution. This paper reports the results of short term laboratory tests of diffusion of chlorine ion through GCL with partially replacing bentonite with flyash. Diffusion coefficient of amended GCL for all replacement levels considered are presented in this reported. Fly replacement levels are varied up to 40% at regular intervals of 5%. The test results indicated that chlorine ion diffusion is reduced for all replacement levels of fly ash. It is concluded that partial replacement of bentonite with fly ash up to 20% is acceptable as diffusion of Chlorine ion increased beyond this replacement level.

Keywords- Geo Textile; Diffusion; Geosynthetic Clay Liners; Flyash; Bentonite

I. INTRODUCTION

A GCL is a manufactured hydraulic barrier consisting of sodium bentonite sandwiched between two woven geotextiles. The geotextile may be a woven one or a non woven one. Bentonite having low permeability imparts better hydraulic performance to the GCL to act as liner, while the geotextile provides better shear strength to the composite. The geotextile also keeps the fine particles of bentonite intact. Over the past decade GCL's have gained wide-spread popularity as a substitute for compacted clay liners in cover systems and composite bottom liners. They are also used as environmental protection barriers in transportation facilities and storage tanks and as single liners for canals, ponds or surface impoundments. As a result, they have been investigated intensively, especially in regard to their hydraulic and diffusion characteristics, chemical compatibility mechanical behaviour, durability and gas migration. Geosynthetic clay liners are thin manufactured hydraulic barriers comprised of a thin layer of bentonite bonded to layers of geotextiles and/or a geomembrane. Presently international standards organizations (ISO) refer to them as clay geosynthetic

barriers. Over the past decade design engineers and environmental engineers have shown great interest in the use of geosynthetic clay liners as an alternative to compacted clay covers or else in some cases bottom lining of waste containment facilities because they often have low hydraulic conductivity and also inexpensive. GCLs are used as environmental protection barriers in transportation facilities (roads and railways) to minimize pollution of subsurface strata from accidental spills and seepage of chemicals or as secondary liners for storage tanks at fuel stations for ground water protection and single liners for canals, ponds or surface impoundments.site.

II. DIFFUSION

At any temperature different from absolute zero, all atoms, irrespective of their state of aggregation (gaseous, liquid or solid), are constantly in motion. Since the movement of particles is associated with collisions, the path of a single particle is a zigzag one. However, an aggregation of "diffusing" particles has an observable drift from places of higher to places of lower concentration (Fig. 1). For this reason diffusion is known as a transport phenomenon.

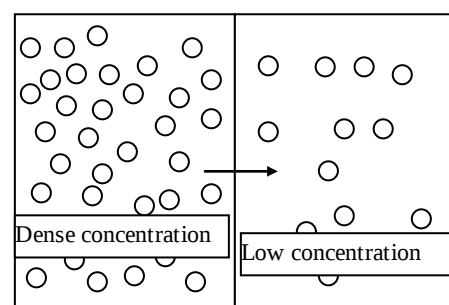


Fig. 1: Diffusion due to differences in concentration.

In a diffusion reaction, the flux (matter, heat, electricity, etc.) follow the general relation:

$$\text{Flux} = (\text{conductivity}) \times (\text{driving force})$$

In the case of atomic or molecular diffusion, the "conductivity" is referred to as the diffusivity or the diffusion constant, and is represented by the Symbol D. The "driving force" for many types of diffusion is the existence of a concentration gradient. The term "gradient" describes

the variation of a given property as a function of distance in the x direction. If a material exhibits a linear variation of concentration with distance in the x-direction, we speak of a constant concentration gradient in the x-direction. The gradient itself is the rate of change of the concentration with distance ($\frac{\partial C}{\partial x}$), which is the same as the slope of a graph of concentration vs. position. Diffusion involves the movement of contaminant from points of higher concentration to points of low chemical potential. Low leachate leakage rates through well-constructed composite barrier systems mean that the advective transport of contaminants is kept to a minimum. As a consequence, diffusion is often considered to be the dominant mode of transport. Short-term (laboratory) diffusion tests, using similar material and solutions to those found in the field, have been shown to ably explain field-scale diffusive migration (1,2). Diffusion coefficients in GCLs for Chlorine (Cl) and Sodium (Na) have been measured by Lake and Rowe (2000) and for Al by Lake et al. (2007). Diffusion coefficients for metals such as As, Ni and Zn in GCLs are reported by Rowe (2009). However, no research has been carried out on the diffusion characteristics of modified or amended GCLs. In this investigation an attempt has been made to measure the diffusion coefficient of GCL in the laboratory.

III. EXPERIMENTAL PROGRAMME

Experimental programme consists of compaction tests and diffusion tests to assess the compaction and diffusion characteristics of amended GCL. Bentonite in GCL is partially replaced by fly ash by 5% up to 40%. Class F fly ash receiving from the Ramagundam Thermal Power Station is used in this investigation. The characteristics of fly ash and bentonite are presented in Table I. Bentonite and fly ash mixture which is used as stuff in Geosynthetic clay liners is compacted at optimum moisture content. Proctors' compaction test is adopted to estimate the optimum moisture content and maximum dry density. Thus prepared GCL is stitched manually so as to enable them for diffusion tests. The different geotechnical properties of fly ash and bentonite mixtures are presented in Table II. Thickness of GCL sample is 25 mm. This includes 12 mm thick geotextiles on either sides of bentonite fly ash mixture. The thickness of bentonite fly ash layer is 13 mm. Diameter of the GCL is 25.4 mm. Thus prepared GCL sample is placed in the mould connecting the two reservoirs of the diffusion testing apparatus (Fig. 2). Two reservoirs are filled with distilled water. The prepared GCL sample is allowed for complete saturation for about 48 hours. After allowing the complete saturation of the GCL sample, required quantity of Sodium chloride is added in one of the reservoir to maintain the concentration gradient for the GCL. The test setup used for conducting the Diffusion tests is presented in Fig. 2. The chlorides concentration in the two reservoirs is estimated using titration method. The concentration is measured at regular intervals of time. The diffusion coefficient is estimated.

C_1 = Source tank concentration (mg/l)

C_2 = Receiver tank concentration (mg/l)

C_2/C_1 = Concentration ratio and

D = Diffusion coefficient (m^2/sec)

The Diffusion coefficient is calculated using the equation

$$\frac{C_2}{C_1} = \text{erf} \left[\frac{T}{2\sqrt{D \cdot t}} \right]$$

T = Thickness of the GCL sample (m)

t = time for each sample has been collected

The titration is repeated for five times and the average value is used to estimate the diffusion.

The diffusion coefficient of the samples tested is presented in Table 3.

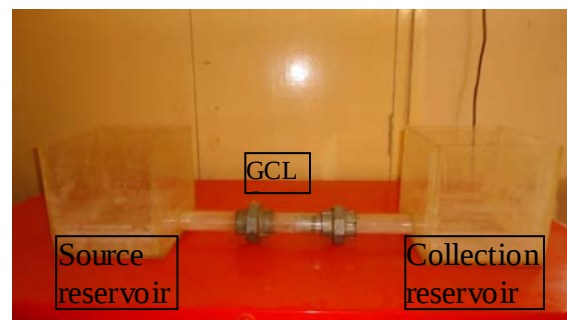


Fig. 2 Experimental setup

Table I PROPERTIES OF BENTONITE AND FLY ASH

Parameter	Bentonite	Fly ash
Specific Gravity	2.75	2.10
Bulk density (kN/m^3)	14.52	13.50
Liquid Limit	265%	22%
Plastic Limit	52%	Not Plastic
Free swell index	430%	No free swell
Optimum Moisture Content	35%	65%

Table II GEOTECHNICAL PROPERTIES OF BENTONITE AND FLY ASH MIXES

Percentage Replacement of Bentonite by Fly Ash	Specific Gravity	Maximum Dry Density (kN/m^3)	Liquid Limit	Plastic Limit	Free Swell Index
0	2.75	14.50	265	52	430
5	2.72	14.50	265	50	400
10	2.69	14.40	262	44	380
15	2.65	14.35	262	42	360
20	2.62	14.20	256	40	330
25	2.58	14.10	240	39	300
30	2.58	14.00	245	36	260
35	2.52	13.70	235	33	220
40	2.49	13.50	230	30	180

Table III VARIATION OF DIFFUSION COEFFICIENT AND OPTIMUM MOISTURE CONTENT

Percentage Replacement of Bentonite by Fly Ash	Diffusion Coefficient of Chlorine in Modified GCL (m^2/s)	Optimum Moisture Content
0	4.53E-10	26
5	3.86E-10	28
10	3.44E-10	29
15	3.17E-10	28
20	2.86E-10	29
25	2.24E-10	30
30	1.77E-10	30
35	1.03E-10	31
40	6.70E-11	32

IV. RESULTS AND DISCUSSIONS

The chloride diffusion coefficient estimated using laboratory diffusion tests is presented in Table III and Fig. 3. From these test results it can be understood that partial replacement of bentonite by fly ash decreases the diffusion coefficient. The reason for this can be attributed to the fact that partial replacement of bentonite by fly ash makes the bentonite-fly ash matrix more cohesive as the fly ash particles are finer and act as ball bearing while getting mixed with bentonite. The decrease in Diffusion coefficient of the resulting modified GCL will provide better performance as liner. The replacement of bentonite by fly ash cannot be continued as this replacement increases the permeability of the resulting GCL. It is reported by Andal Mudimby et.al (4) that the increase in the permeability of modified GCL (partially replacing bentonite by fly ash to the tune of 25% replacement) does not cross the stipulation of permeability as liner 1×10^{-9} m/s. The variation of optimum moisture content of different mixtures considered in this investigation was presented in Table 3 and Fig. 3. From these variations, it is clear that when bentonite is partially replaced by fly ash, there is an increase in the Optimum moisture content. The reason for this increase in optimum moisture content can be attributed to the fact that partial replacement of bentonite by fly ash increases the surface area of the resulting matrix. From economic view, replacement of bentonite by fly ash up to 25% can be advocated as the permeability of the resulting GCL is less than 1×10^{-9} m/s and Chloride diffusion coefficient is less than that of virgin GCL.

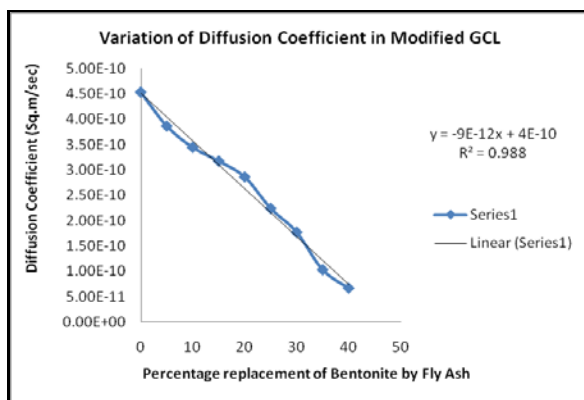


Fig. 3 Variation of Diffusion Coefficient for Amended GCL

V. CONCLUSIONS

Based on the laboratory diffusion test results on modified GCL partially replacing bentonite with fly ash, the following conclusions are drawn.

1. Partial replacement of bentonite by fly ash decreases the coefficient of diffusion through modified GCL.
2. Partial replacement of bentonite by fly ash is an encouraging aspect from the performance point of view of GCL; however, this replacement level shall be restricted to 25%, as permeability of modified GCL increases adversely beyond this replacement level.
3. The laboratory diffusion tests are conducted taking into consideration the chloride diffusion only through modified GCLs. The other chemicals are also need to be investigated.

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REFERENCES

- [1] Lake, C.B., Rowe, R.K., 2000. Diffusion of sodium and chloride through geosynthetic clay liners. *Geotextiles and Geomembranes* 18 (2-4), 103-131.
- [2] Bouazza, A., 2002. Geosynthetic clay liners (Review Article) *Geotextiles and Geomembranes* 20 (3-17).
- [3] Bouazza, A., Vangpaisal, T., 2004. Effect of straining on gas advective flow of a needle – punched GCL. *Geosynthetics International* 11(4), 287-295.
- [4] Rowe, R. K., Brachman, R. W. I., 2004. Assessment of equivalence of composite liners. *Geosynthetics International* 11(4), 273-286.
- [5] C.B. Lake ,et.al.(2007),Aluminium migration through a Geosynthetic clay liner, *Geosynthetics International*, Vo. 14,No. 4,2007, pp 201-210
- [6] Cokca, E., and Yilmaz, Z. (2004). "Use of rubber and bentonite added fly ash as a liner material". *Waste Management*, 24 (2), 153-164.
- [7] Lange, K., Rowe, R. K. and Jamieson, H., 2009. Diffusion of metals in geosynthetic clay liners, *Geosynthetics International*, Vol. 16, No. 1, 11-27.
- [8] Andal Mudimby., Chandrasekhar, M and Viswanadh, G.K., 2011. Hydraulic Conductivity of ameliorated Geosynthetic Clay Liners. *Electronic Journal of Geotechnical Engineering*, Vol. 16, Bund. O, 1362-1368.



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